Importance of core polarization in halo nuclei

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Recently Kuo, Krpotić, and Tzeng studied the core polarization effect in ^{6}He and ^{11}Li [1]. They found that the effect is dramatically suppressed in these halo nuclei compared to more stable systems. I would like to point out that the core polarization, although suppressed, still plays an extremely important role in the binding mechanism of halo nuclei.

The neutron halo nuclei generally have very small binding energies relative to breakup thresholds, and the three-body halos (like ^{6}He and ^{11}Li) usually do not have any bound two-body subsystem. These facts indicate that the most important degrees of freedom are the core+n(+n) relative motion(s). That is why the various cluster models of these nuclei are so successful [2]. If one wants to understand the binding mechanism of halo nuclei one has to use a model which treats these relative motions rigorously and, in addition, reproduces the core+n and $n+n$ scattering observables. It has been known for a long time that such models underbind the $A = 6$ nuclei, including ^{6}He [3]. Moreover, the ^{11}Li nucleus was found to be unbound in such a rigorous three-body model [4], although this fact is less well established because of the sparse ^{9}Li+n data. The authors of Ref. [4] suggested that if one could take into account effects where the core is excited through interacting with one halo neutron and deexcited by interacting with the other halo neutron, then the missing binding energy might be recovered. This three-body excitation-deexcitation mechanism is a physical picture of the core polarization effect.

In Ref. [5] I studied this effect in a six-body, three-cluster (α+n+n) model of ^{6}He. In a simple model, where the alpha particle was not excitable, the two-neutron separation energy of ^{6}He was 0.64 MeV, while the experimental value is 0.975 MeV. The model reproduced the experimental $\alpha + n$ and $n + n$ phase shifts, so the same underbinding problem occured as before [3]. In a more sophisticated model, the possibility of monopole α-particle excitations were included by allowing several harmonic oscillator size parameters for the α-particle. It was found that this improvement did not have any observable effect on α+n scattering. However, the two-neutron separation energy of ^{6}He became 0.74 MeV, 15% more than in the simpler model. The insensitivity of $\alpha + n$ and the sensitivity of $\alpha + n + n$ on the inclusion of α excitation into the model is a clear, although indirect, indication that this 15% energy gain comes from the core excitation-deexcitation mechanism, described above.

In [5] an even more important core-halo effect was also found. The α-particle can break up and together with the halo neutrons can form two ^{3}H particles. The inclusion of this effect in the model of [5] led to the reproduction of the experimental two-neutron separation energy of ^{6}He in a parameter free model. As the ^{9}Li core of ^{11}Li is much softer than the α-particle, these effects are expected to play a much bigger role in ^{11}Li

In summary, although core polarization is suppressed in neutron halos, it plays an essential role in the binding mechanism of these nuclei.

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